

CONTROVERSIES

Learning curves in surgical practice

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Learning curves are often referred to in the context of medical education and training, though their trajectories and natures are a matter of debate. The origins of this concept derive from industry and its relevance to contemporary medicine and surgery remains controversial. We describe the history, derivation, character and possible mechanisms to deal with the implications of learning curves in the current climate of clinical governance and modernising medical careers.

requirement, duration of stay in high dependency or intensive care, length of stay in hospital, morbidity rates, mortality rates, and cumulative survival. Process outcomes are generally easier to analyse and therefore more commonly used, though they are only indirectly related to patient outcomes.¹

In 1979, Luft *et al*⁸ reported a possible relationship between volume of clinical work and outcomes, but despite other supporting studies, controversy remains regarding the importance of the complexity of the condition, the existence of threshold volumes, and the relative roles of individual clinicians versus unit or hospital volumes. The need for appropriate indices of outcomes has been recognised, but the information available is derived from simplistic statistics evaluating outcomes in terms of mortality, which allows little opportunity for assessing risk. Moreover, for clinical procedures with few associated complications, operative mortality is an inappropriate index, and other indices of effectiveness such as operative morbidity, patient satisfaction and quality of life are more appropriate. Multidimensional plots taking into account all significant variables are most likely to give the most accurate representation of a specific operation's learning curve.

When considering outcomes of cancer surgery, improvements in case adjusted long term survival probably represent the best measure of performance. Indeed, it is possible to plot curves based on long term survival related to progression within a case series. Such calculations, however, require considerable time before analysis, and, if cumulative survival is poor, then a problematic procedure or incompetent clinician may not be identified for some considerable time. Further research into identifying suitable and reliable measures of outcome is required.

When learning a new procedure, performance tends to improve with experience, and graphically plotting performance against experience produces a learning curve.^{1–5} Clinicians inexperienced in a procedure are said to be on the early phase of their learning curve with improvements expected with increasing experience. This concept applies across the full spectrum of medical specialities and procedures; however, with the advent of technically demanding minimally invasive techniques, it is surgery in particular where there are specific and potentially dramatic implications. The clinical importance of this was brought into stark relief by the General Medical Council inquiry into the Bristol Paediatric Surgical Unit, which stated that patients should not be exposed to surgeons operating during the early phase of their learning curves.⁶

In this article we aim to describe the historical time line of the learning curve concept, address the common misnomer that steep learning curves are associated with difficult and complex procedures, suggest methods by which surgical learning curves may be constructed, and describe their relevance to modern medical training.

MEASURING OUTCOMES

In 1936, TP Wright, an aeronautical engineer, published the first description of a learning curve.⁷ His thesis was that speed or efficiency of airplane component production increased, and cost decreased, as the experience and skill of the workforce increased. In industry, measures of performance are often obvious—for example, production time, costs, and quality control. However, it is more difficult to assess a clinicians' performance. Measures of learning related to a surgical technique fall into two categories: measures of surgical process, and measures of patient outcome. Surgical process measures include operative factors such as operative time, blood loss, and technical adequacy of resection for cancer surgery—margin involvement and lymph node yield. Patient outcomes include postoperative factors such as analgesia requirement, transfusion

PLOTTING A LEARNING CURVE

A hypothetical plot is illustrated in fig 1, which has four main phases. The starting coordinate A, represents commencement of training. Secondly, the curve ascends. The gradient of this ascent indicates how quickly the individuals' performance improves; this part of the curve may be a stepwise ascent as individuals learn and master stages of a complex procedure. Improvements in performance tend to be most rapid at first and then tail off, as the degree of improvement attained with each case reduces as technique is refined. Thirdly, assuming adequate aptitude, a point is reached when the procedure can be performed independently and competently (coordinate B). Additional experience improves outcomes by small amounts (coordinate C), until a plateau, or asymptote, is reached (coordinate D). Fourthly, with advancing age, manual dexterity, eyesight, memory and cognition

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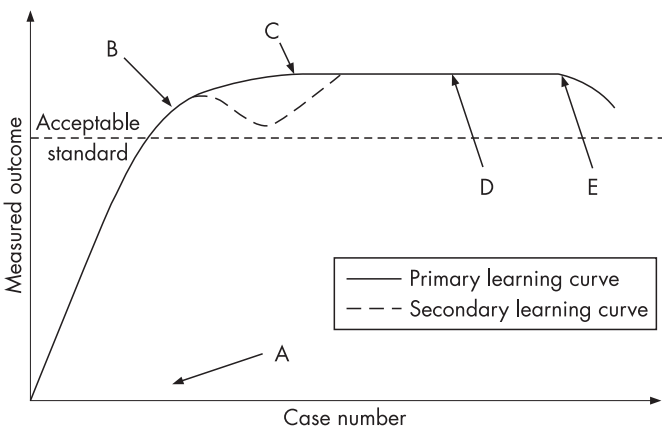


Figure 1 Idealised surgical learning curve.

may deteriorate, outweighing any advantage derived from long experience, leading to a fall in the level of performance (coordinate E).^{9 10} An alternative curve has also been described (dotted line),¹¹ which exhibits temporary performance deterioration after technical competence has been achieved. The reasons postulated are case mix effect (undertaking more difficult cases), or over confidence resulting in lapses in technique or judgement.

THE STEEP LEARNING CURVE MISNOMER

A procedure with difficult and complex steps is often termed as having a steep learning curve, and certainly in mountaineering terms steepness usually equates to difficulty. However, steepness can equally relate to climbing and gaining height rapidly. Similarly, it may be argued that a steep learning curve implies that skills are acquired rapidly, usually because the procedure is simple. Complicated and technically demanding procedures are often described erroneously as having a steep learning curve, which implies large improvements in outcomes are achieved early in a case series, and competence (coordinate B) is achieved after relatively short experience. In fact, complex procedures are more likely to have gradual learning curves, with small improvements in outcome associated with each passing case, such that coordinate B is achieved only after large experience or not at all.

IDENTIFYING CLINICIANS’ POSITIONS ON LEARNING CURVES

By measuring specific outcomes it is possible to estimate the location of an individual on a learning curve; the spectrum of

reported measures of outcome related to attainment of the plateau phase is shown in table 1.

Serial monitoring of outcomes allows an estimate of the procedure specific gradient of the curve related to a particular individual. Caseload information allows inter-clinician comparison, although variations in case mix must be considered. Contemporary specialist clinicians work within the framework of multidisciplinary teams (MDT) of clinicians and allied professionals. Not only may an individual’s performance improve with experience, but also that of other members of the team. Discriminating between specific improvements may be difficult if not impossible, and in reality, the learning curve may be a composite measure of MDT performance related to experience.

CONCLUSION AND IMPLICATIONS FOR MEDICAL TRAINING

Consultant appointments in the National Health Service in the UK occur after a defined training period. Nevertheless, outcomes improve with experience and trainees will be appointed to consultant posts while still on a number of different learning curves and short of the expert phase for certain procedures.^{2 3 5 12} In this environment, the challenge becomes providing enough time and employing teaching strategies that facilitate universal achievement. The key elements in learning are: unequivocal definition of what is to be learned and how it will be evaluated; allowing trainees to learn at their own pace; assessment of progress with appropriate feedback; and testing that the expert phase has been achieved. The introduction of the intercollegiate surgical curriculum pilot study of direct observation of procedural skills (surgical DOPS) will provide important information in this regard and will potentially help to meet these goals.¹⁷ Allied to such initiatives, and as supervised training opportunities reduce,^{18 19} newly appointed consultants must recognise the need for continuing post-accreditation training, structured appraisal, and senior mentors in order to facilitate continuing medical education so that acceptable outcomes may be achieved and maintained.

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Table 1 Measures of outcome related to duration of time taken to achieve competence

Surgical procedure	Outcome	Time or number of cases to plateau	Reference
Laparoscopic fundoplication	Complication rate, conversion to open procedure, reoperation rate	20 cases	Meinke and Kossuth ¹²
Laparoscopic colorectal surgery	Conversion to open procedure, complication rate, operative time	55–80 cases	Tekkis <i>et al</i> ^{3 14}
Laparoscopic cholecystectomy	Bile duct injury rate	3 years	Richardson <i>et al</i> ⁵
D2 gastrectomy	Morbidity, mortality, LN harvest	18–24 months 15–25 cases	Parikh <i>et al</i> ⁶
Oesophagectomy	Operative time, blood loss, ITU stay, inpatient stay, LN harvest	Continuing improvement at 7 years or 150 cases	Sutton <i>et al</i> ⁶
Coronary artery surgery	Mortality	4 years	Bridgewater <i>et al</i> ⁶

ITU, intensive therapy unit; LN, lymph node.

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